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(54) Measuring and treatment tool incorporating broadband stripline aerials and useful in medical technology

(57) The tool, for determining the nature of fluid in mammal tissue or cancer therapy by hyperthermia transmits, and optionally receives electromagnetic radiation over a broad band of 2KHz – 1GHz and can determine resistivity and dielectric constant. It incorporates at least one transmitting and receiving antenna. Each antenna comprises a coaxial cable 151 connected to stripline adapter 153, which is connected to a stripline (155) having a metallic central strip (159). A strip face 161 is bent at approximately right angles, and has a length that is compatible with the desired frequency coverage. A ground plane 165 extends from the stripline adapter to the right angle bend, and a dielectric 167 fills the space between the centre strip and the ground plane. An enclosure comprising four metallic walls 181 surrounds the stripline, and is in electrical contact with the ground plane and the stripline adapter and a lossless, non-conducting material fills the enclosure. The antennae are positioned so that the strip face lies flush with the tool face, to permit electromagnetic energy to be transmitted into and out of the material to be analyzed. Amplitude and phase of the received signal are monitored.

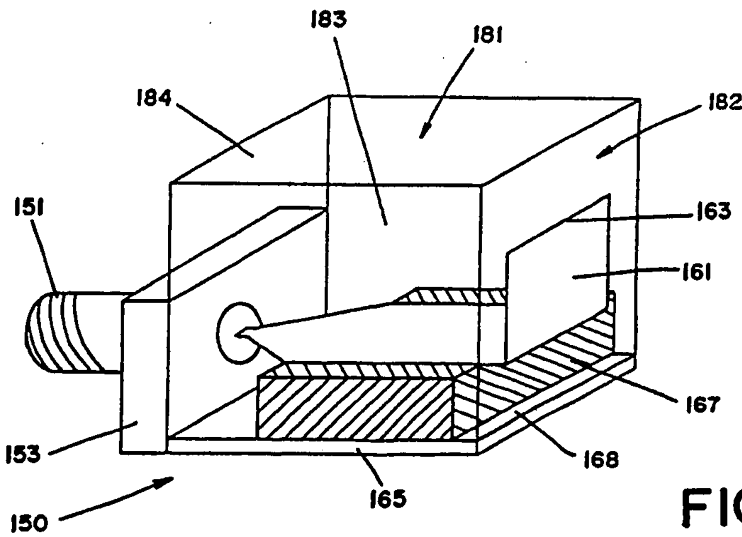

FIG_2A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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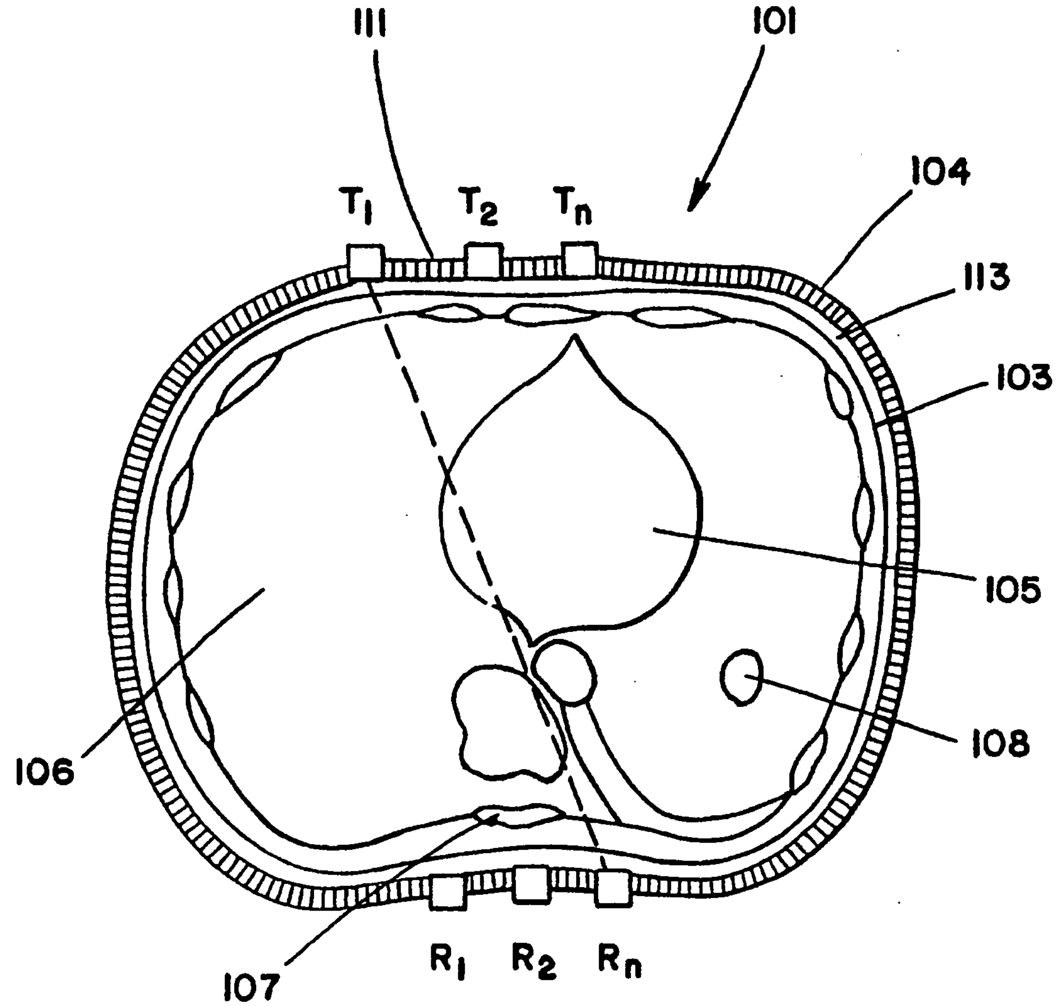

FIG_1

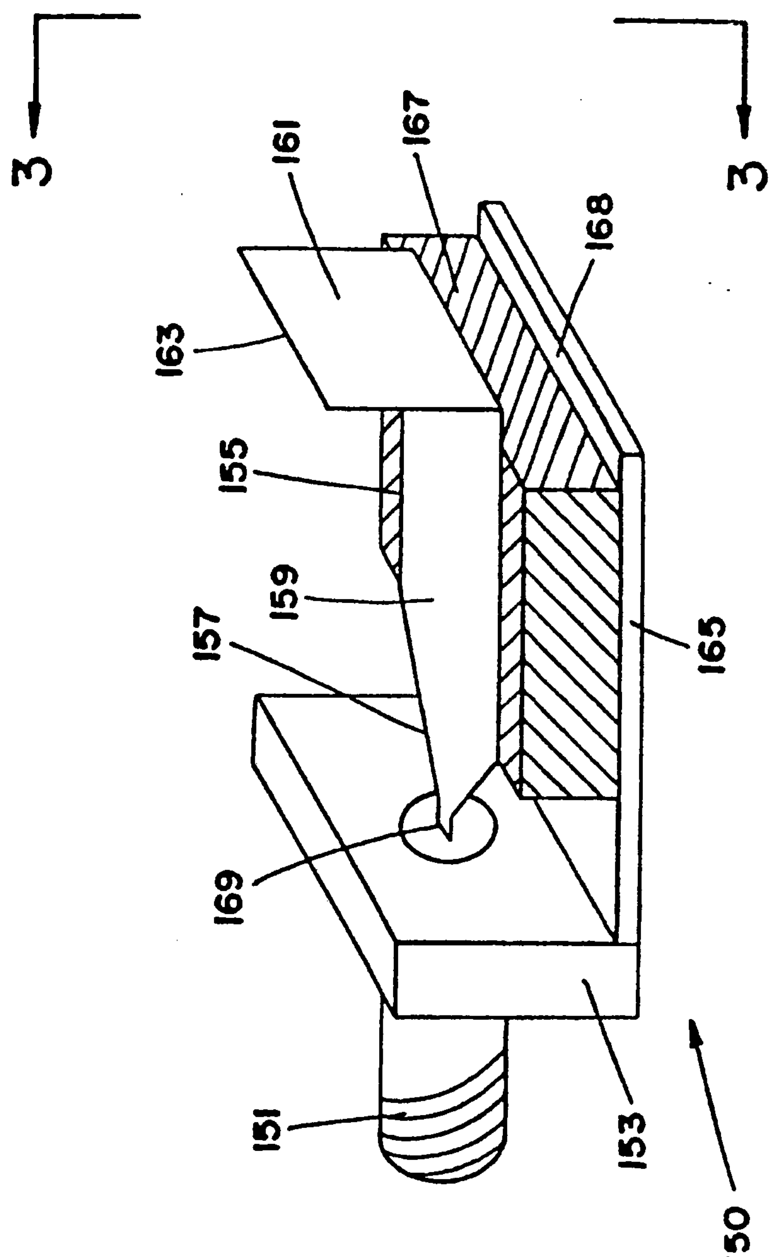

FIG_2

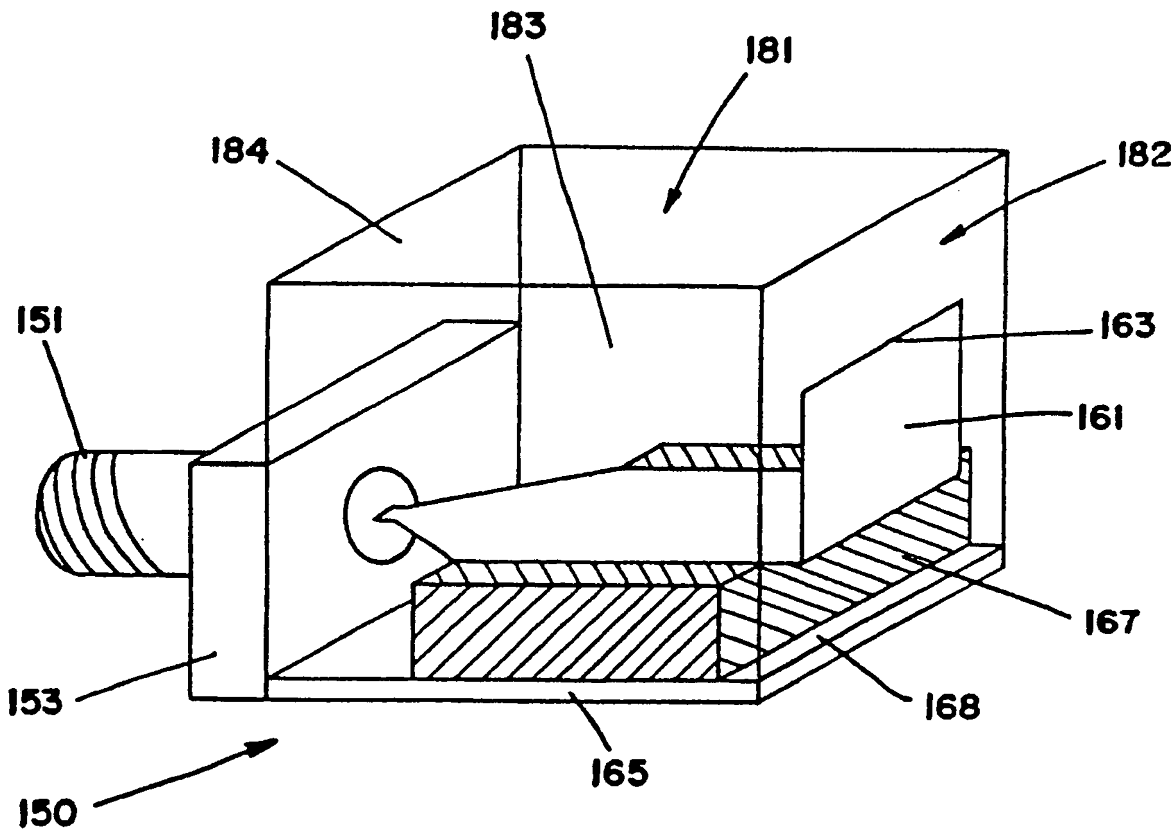

FIG_2A

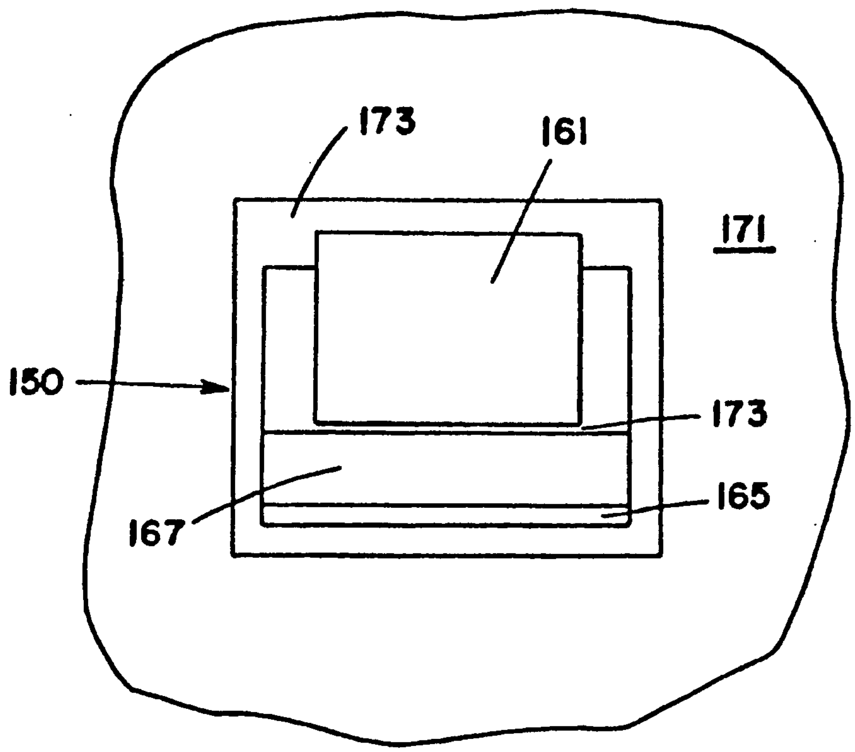

FIG_3

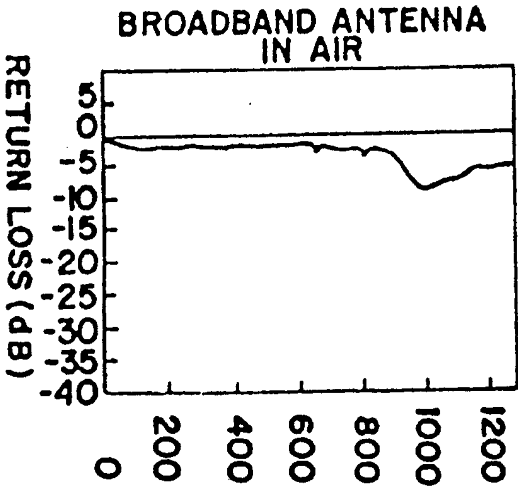

FIG_4A

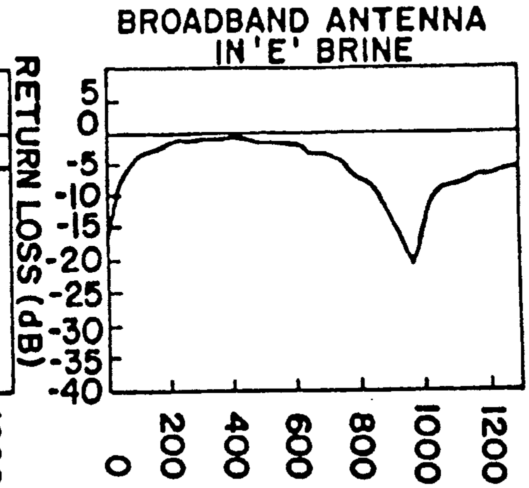

FIG_4B

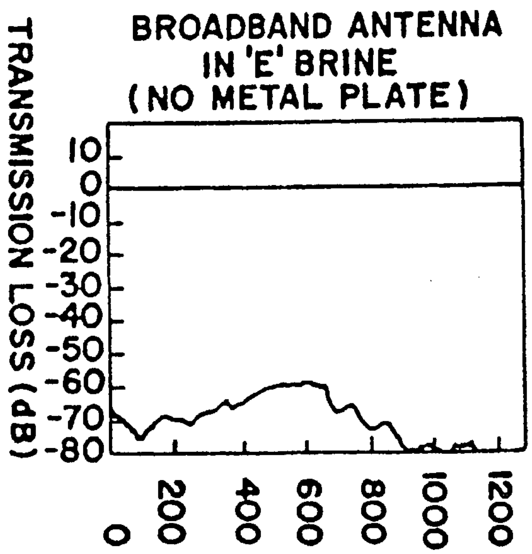

FIG_4C

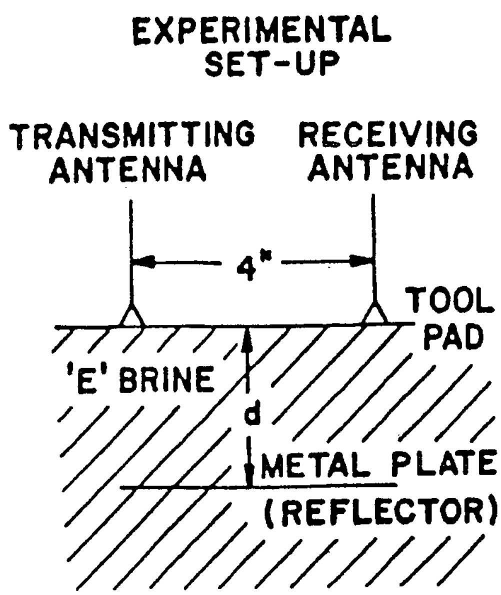

FIG_4D

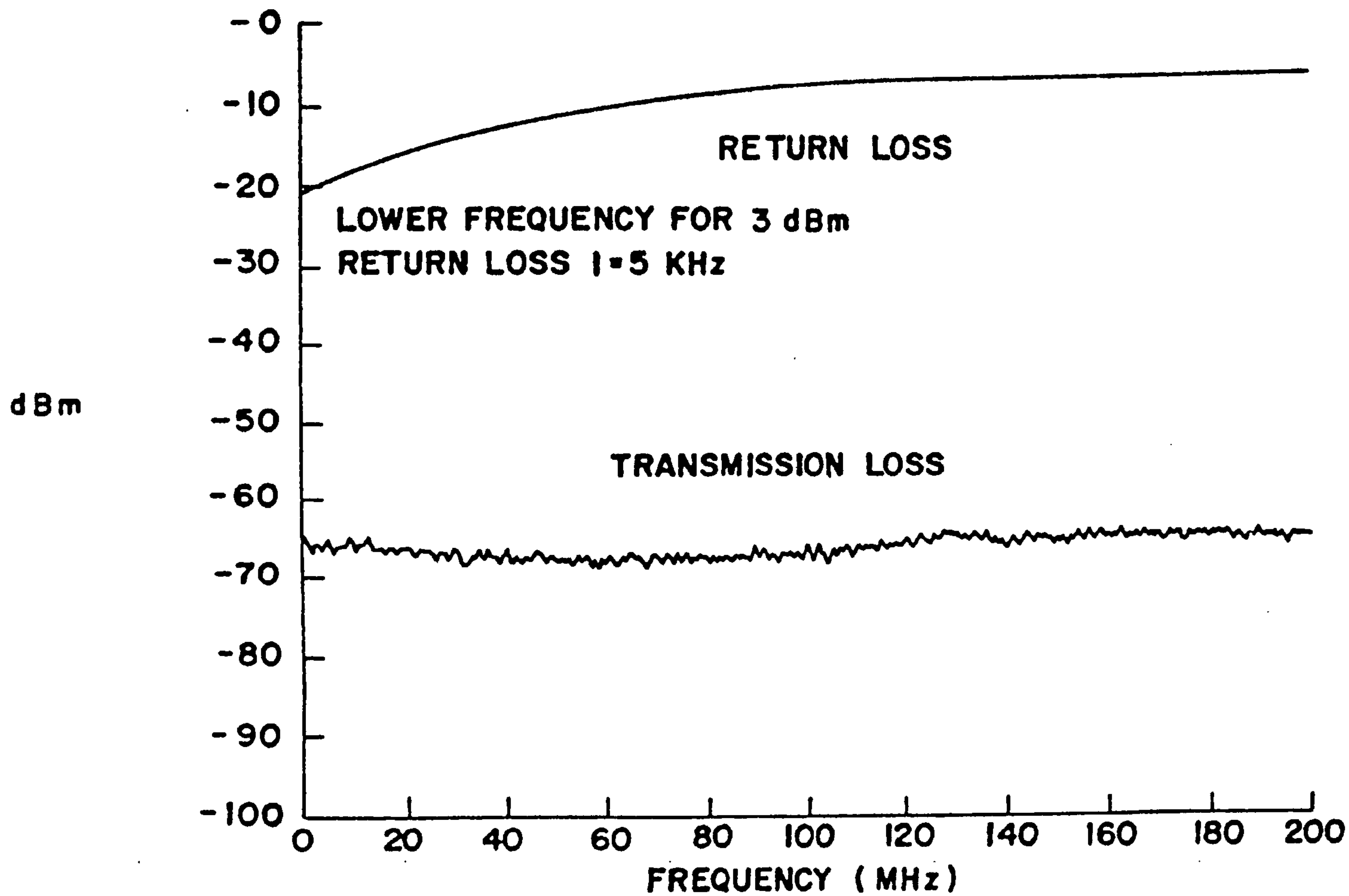
-0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
dBm
RETURN LOSS
LOWER FREQUENCY FOR 3 dBm
RETURN LOSS 1=5 KHz
TRANSMISSION LOSS
0
20
40
60
80
100
120
140
160
180
200
FREQUENCY (MHz)

FIG_5

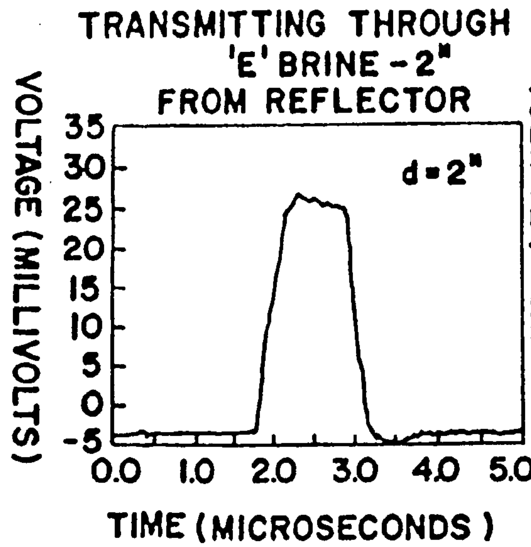

FIG_6A

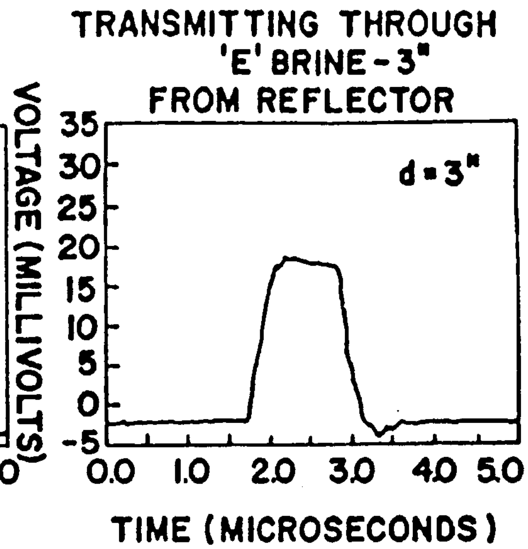

FIG_6B

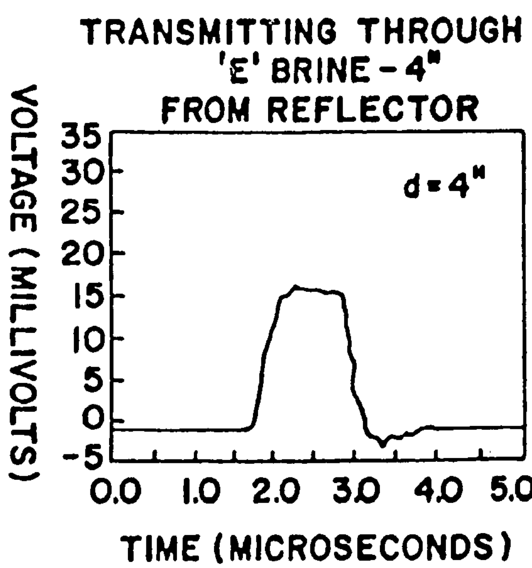

FIG_6C

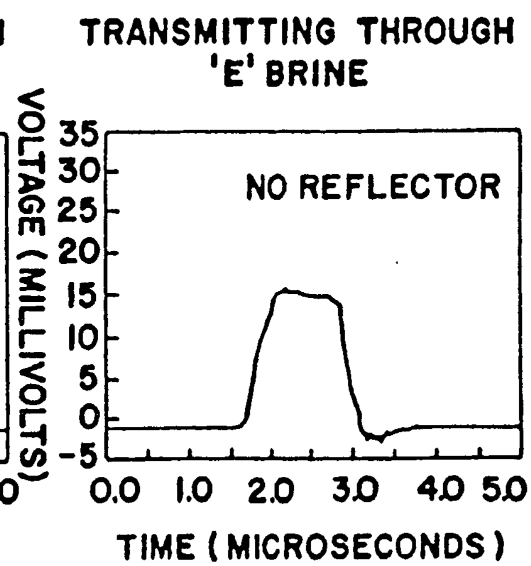

FIG_6D

METHOD AND APPARATUS FOR BROADBAND ELECTROMAGNETIC ENERGY COUPLING

The present invention relates generally to the electromagnetic coupling and analysis. More specifically, this invention provides an antenna which can combine the functions of various resistivity and dielectric constant devices into a single tool, capable of operating over a wide range of frequencies. It is particularly useful in the field of medical technology.

In the field of medical technology, it is well known that electromagnetic energy is useful in various types of diagnoses and treatments. For example, recent statistics show that pulmonary and cardiopulmonary diseases are responsible for more than three million hospital admissions and 30,000 deaths every year in the United States. Pulmonary abnormalities are virtually always associated with changes in lung water content or distribution. Most workers agree that there is no single, nondestructive method available to detect accurately early changes in lung water content.

For a clinically useful technique, it is desirable to detect early changes in both the extravascular lung water, which strongly reflects most pulmonary abnormalities, and the intravascular compartment. Recently, the use of the electromagnetic methods to detect changes in lung water content have shown promising initial results, particularly for detecting small variations in water content.

Particularly at microwave frequencies, changes in the dielectric properties of tissue are closely related to the amount of water present. Electromagnetic techniques, therefore, basically utilize changes in the permittivity and conductivity of the lung region to detect changes in lung water content. This method has the advantage of using highly penetrating electromagnetic signals rather than ultrasonic signals which are both highly attenuated and dispersed in the lung. Furthermore, electromagnetic techniques have the potential for continuous monitoring of patients in intensive care units, such as those with heart failure or extensive burns.

U.S. Patent No. 4,240,445 issued to Iskander et al. and is incorporated herein by reference for all purposes. Iskander teaches a method of coupling electromagnetic energy into a material such as tissue, to measure water content. Measuring lung water content is an especially useful application. However, Iskander's device is so large that only a few antennas can be place on the chest, and the antenna cannot be described as a point source. Also, the electric field vanishes at some distance from the antenna, as the electric fields in the two parallel slots are oppositely directed. Furthermore, a resistor is included in the antenna, which dissipates much of the electromagnetic energy in the antenna itself and introduces a limitation in the power handling capability of the antenna. Additional prior work includes: M. F. Iskander and C. H. Durney (1980): "Electromagnetic Techniques for Medical Diagnosis: A Review", Proceedings of IEEE, vol. 68, no. 1. and M. F. Iskander et al (1982): "Two-dimensional Technique to Calculate the EM Power Deposition Pattern in the Human Body", Journal of Microwave Power, vol. 17, no. 3. There is thus a need for a device that is compact enough to permit

placing of many antennas forming an array on a chest to obtain a well-defined image of the chest cavity, a device that has an antenna that can be mathematically described as a point source, and one which does not suffer from cancellation of the electric field at a certain distance.

A dielectric transmitting and measuring device can also be used to heat an interior portion of a mammalian body to destroy or reduce the size of tumors. Tumor reduction therapy, or cancer therapy by hyperthermia, combined with radiation or drugs is known in the art to either stop or slow down the growth of cancer cells, or cause the death of the cancer cells. (See, for example, Streffer, C., "Cancer Therapy by Hyperthermia and Radiation", Urban and Schwarzenberg, Munich, F.R.G., 1980 and Dethylefsen, L.A. (Editor), "The Third International Symposium: Cancer Therapy by Hyperthermia, Drugs and Radiation, Colorado State University, Ft. Collins, U.S.A., 1980.)

One such device is disclosed by J. Scheiblich et al. "Radiofrequency-Induced Hyperthermia in the Prostate", Journal of Microwave Power, vol. 17, no. 3, 1982, Ottawa, Canada. Scheiblich et al's device works only at a single frequency.

A propagating electromagnetic wave has two fundamental characteristics, amplitude and phase. By comparing the amplitude and phase of an electromagnetic wave as it passes receivers, propagation characteristics of the probed medium may be studied. Measurement of these two characteristics may be used to determine the dielectric constant and the conductivity of the media through which the wave is propagated.

However, no one tool in the prior art is capable of probing or coupling energy into a material over a broad band of frequencies. It is therefore advantageous to extend the frequency range.

The largest hurdle to developing such a broadband dielectric tool has been the lack of a suitable broadband antenna that can couple electromagnetic energy to and from a material, and that is compact enough to fit within the confines of a tool.

The prior work is limited in the attempts at electromagnetic coupling, analysis, and treatment, in that no suitable single antenna element has been designed which can couple electromagnetic energy into a material, such as mammal tissue, over a broad range of frequencies, that is also sufficiently compact and is capable of handling high power levels. There is therefore a need for a device and a method for use in such broadband applications.

The present invention is surprisingly successful in providing a method and apparatus for combining the functions of various conductivity and dielectric constant devices and electromagnetic energy coupling devices into a single device, capable of operating over a wide range of frequencies. It is especially useful in medical technology applications.

A measuring or electromagnetic coupling tool, having a tool face, also has a novel transmitting antenna and a novel receiving antenna. Electromagnetic energy is transmitted to a transmitting antenna. A stripline adapter permits the

energy to flow to a stripline having a metallic central strip. A strip face of the central strip is bent at approximately right angles, and has a height that is compatible with desired frequency coverage.

A ground plane extends from the stripline adapter to the right angle bend, so that a distal end of the central strip extends away from it, and a void is created between the center strip and the ground plane.

A dielectric is positioned to nearly fill the void. The dielectric is comprised of a material having a very high dielectric constant and a very low energy loss. The transmitting antenna is positioned so that the ground plane is fixedly connected to the measuring tool, and the strip face lies flush with the tool face, so that electromagnetic energy can be transmitted into the material to be analyzed.

An enclosure surrounding the stripline is comprised of four metallic walls which are positioned in electrical contact with the ground plane and the stripline adapter, so that the strip face is nearly centered in the opening created by the walls and the ground plane.

A loss-less, non-conducting material fills in any remaining open space in the enclosure, so that the non-conducting material forms an additional wall that is really flat with the strip face.

A receiving antenna is comprised in essentially the same manner as the transmitting antenna, and is positioned in the tool so that it can receive the electromagnetic energy which has traveled through the material being probed. A means for

monitoring the received energy detects the phase and the amplitude.

In another embodiment of this invention, broadband measurements are taken to determine the quantity of a fluid in a material, such as water in a lung.

It is one object of this invention that electromagnetic energy is transmitted and received over a wide frequency range, specifically from a few KHz to a few GHz. A commonly used frequency range is from 2 KHz to 4 GHz.

The tool may further comprise a pad, which substantially conforms to the surface of the mammal tissue, and holds the antennas. At least one transmitting antenna is necessary. No receiving antenna is necessary, although a plurality of each is often desirable.

The above and other embodiments, objects, advantages, and features of the invention will become more readily apparent from the following detailed description of the invention, which is provided in connection with the accompanying drawings.

Figure 1 is a schematic, sectional view of the inventive device positioned adjacent to mammal tissue.

Figure 2 shows a top, front, and side view of the novel transmitting antenna.

Figure 2A is the same view as Figure 2, further illustrating the enclosing metallic walls.

Figure 3 shows an antenna mounted on a tool face.

Figure 4 shows three graphs of transmission and return loss as a function of frequency.

Figure 5 is a graph of transmission and return loss as a function of frequency, for low frequencies.

Figure 6 shows four graphs of time-domain transmission measurements at various distances from a metal reflector plate in a brine.

In accordance with the present invention, a new improved method and apparatus for coupling electromagnetic energy into a material for determining the nature of various materials and the fluids contained therein and to induce hyperthermia, using a broadband measuring apparatus, has been developed.

Referring to the drawings, a first embodiment of the inventive broadband tool 101 is shown in Figure 1, positioned around a portion of a mammal body such as a chest cavity 103. A means such as a belt mount 109 positions tool face 111 near the mammal skin 104, such that transmitting antennas such as T1 and T2 and receiving antennas such as R1 and R2 are positioned touching the skin surface of 104. The tool face 111 is defined as the surface of the belt mount 109 containing the aperture plane of the antennas, and is preferably a continuous metallic surface. The belt mount 109 may be made of any suitable flexible material that can be strapped around the portion of interest of the mammal

body. A conducting compound such as a conducting grease may be applied at the interface 113 between the tool face 111 and the skin surface 104 to improve coupling between the antennas and the chest cavity 103.

The region of the mammal body to be investigated may not be electrically homogeneous. In the chest cavity 103 for example, there are organs such as the heart 105, the lung region 106, the vertebra 107, and there may also be a tumor 108. It is often desirable to analyze or treat selected portions of such a cavity 103.

An analysis of the chest cavity 103, for example, can be done by a dielectric imaging of the cavity. This is done by transmitting electromagnetic energy at a suitable frequency across the chest cavity 103 from a transmitting antenna such as T1, and receiving this energy at a receiving antenna such as Rn. In this way the phase and the amplitude of the propagated electromagnetic wave for the path T1Rn (shown in dashed line) is determined. Since there can be a multiplicity of transmitting antennas Tn and a multiplicity of receiving antennas Rn, a multiplicity of such paths crisscrossing the entire chest cavity can be studied. From this information, using well known techniques, a dielectric image of the chest cavity can be generated. Such an image displays the various organs in the cavity, and when suitably made, can reveal the presence of tumor 108. The dielectric properties, and thus a dielectric image, can be determined as a function of position within the material being probed. Since dielectric image is very sensitive to the presence of water, it can also give an assessment of the lung water content; Cf. "Microwave Methods of Measuring Changes in Lung Water", by M. F. Iskander and C. H. Durney, Journal of Microwave Power, vol. 18(3), 1983, p. 265.

Note that although the antennas have been labeled as either transmitting or receiving antennas, any given antenna can serve either function.

The broadband capability of the antennas is an advantage in the above applications for the following reasons: structures (e.g., heart, tumor) of different sizes require different frequencies for their best definition in the image; highly lossy regions such as fluids may require employment of relatively low frequencies so that the electromagnetic losses are acceptable; in time-domain application, simultaneous information at a multiplicity of frequencies can be developed.

In the treatment mode, it is desirable to reduce or eliminate the tumor 108 by hyperthermia, i.e., by selectively heating only the tumor region 108 to a high temperature. Thus, by selecting a suitable group of antennas to transmit, one can selectively deposit electromagnetic energy in the region of the tumor 108; Cf. "Two-dimensional Technique to Calculate the EM Power Deposition Pattern in the Human Body", by M. F. Iskander, P. F. Turner, J. B. DuBow and J. Kao, Journal of Microwave Power, vol. 17(3), 1982, p. 175.

The broadband capability of the antennas is an advantage in the above application because for a given situation, one can select the frequency that simultaneously produces the optimum deposition of power and localization of the heating using known techniques.

An example of the inventive transmitting antenna 150 is shown in Figure 2. A coaxial connecting means, such as

coaxial connector 151 is electrically connected to a stripline adapter 153 which is capable of transmitting electromagnetic energy from the coaxial connector 151 to a stripline section with metallic central strip 155. An especially useful stripline adapter is a model No. 3070-1404-10 designed by Omni-Spectra, or other types of microwave stripline adapters. Other types of transmission means may be utilized to transmit electromagnetic energy to the antenna. For example, a strip transmission line may be electrically connected to the stripline section having the metallic central strip 155. As a commercial coaxial-to-stripline transition means has been utilized, the dimensions included herein reflect this means. One knowledgeable in the art would realize that the dimensions may be altered to change frequency coverage and to fine-tune performance.

Metallic center strip 155 has a front end 157, a flat strip body 159, a flat strip face 161, and a distal end 163. The front end 157 is electrically connected to the center conductor 169 of the stripline adapter 153. Solder is a particularly useful connecting means. Flat strip body 159 may also be tapered to come to a point at front end 157 to provide a smooth electrical transition between the center conductor 169 and the center strip 155. The strip face 161 is bent at approximately right angles to strip body 159, and has a height that is measured from the right angle bend to distal end 163. The height is compatible with the desired frequency coverage. The longer the height, the more lower frequency coverage is allowed. A ¼" height permits a frequency range of approximately 2 KHz → 1 GHz. A 5mm height extends the upper frequency limit to approximately 2 GHz. An upward frequency limit of 4 GHz is attainable as

well. The metallic center strip 155 can be made of any metal. Copper, brass, or aluminum are especially useful.

A ground plane 165 extends from stripline adapter 153 to the right angle bend in the center strip 155, so that the distal end 163 extends away from the ground plane 165 and so that a void exists between the center strip 155 and the ground plane 165. Ground plane 165 is comprised of a metal. Commercial grade stainless steel is particularly useful. It is desirable to keep the ground plane and center strip as short at possible, to permit the apparatus to remain as compact as possible and to allow the use of as many antennas as possible.

The void between the ground plane 165 and the center strip 155 is largely filled with a dielectric 167. The dielectric 167 should have a very high dielectric constant and a very low loss. By loss, we mean the dissipation of energy. The dielectric 167 can be a ceramic dielectric, and comprised of material such as Barium Titanate or Lead Zirconate Titanate. A crystalline dielectric may also be used, although more expensive. The thickness of the dielectric 167 is determined by the stripline adapter 153 used. The dielectric 167 acts to make the capacitance of the center strip 155 very large.

The construction of the antenna is completed by enclosing the center strip 155 by metallic walls 181, 182, 183, and 184, which contact the ground plane 165 and the adapter 153 electrically, as shown in Figure 2A. The walls add rigidity and prevent leakage of the electromagnetic radiation. The strip face 161 is approximately centered in the rectangular opening created by the edges of the walls and the edge of the ground plane 165. Thus, the distance between an edge of

the strip face 161 and the adjacent edge of a wall is substantially the thickness of the dielectric 167. The entire void space in the antenna enclosed by the walls, including the set back 168 at the dielectric edge, is filled with a loss-less, non-conducting material such as a mixture of epoxy and alumina which sets hard, seals the antenna, and makes it more rugged.

The ground plane 165 and the walls 181, 182, 183, and 184 are fixedly connected to an electromagnetic coupling or analyzing tool as seen in Figure 3. The strip face 161 is positioned to lie flush with the tool face 171 (which is the same as the tool face 111 of Figure 1), so that the transmitting antenna 150 can transmit electromagnetic energy into a material such as mammal tissue. A conductive substance, known in the art, is usually placed on the outside of the mammal tissue, to permit a sufficient flow of electromagnetic energy into the tissue. Void space 173 is filled with a loss-less, non-conducting material such as an epoxy-aluminum compound. The ground plane 165 and the walls 181, 182, and 183 connect to the tool face.

A receiving electromagnetic antenna is comprised in essentially the same manner as the transmitting antenna, and is positioned in the tool in the same manner as the transmitting antenna, so that the receiving antenna can receive the electromagnetic energy which has traveled through the material that is analyzed.

The present invention is especially useful in the field of microwave diagnostics of fluid content and fluid quantity. For example, the apparatus can couple electromagnetic energy into mammal tissue. The electromagnetic energy can be monitored to provide an indication of the amount and

distribution of a fluid, such as water, inside the mammal tissue. One particularly useful application is to measure the water content in a lung. The present apparatus is very compact, and therefore requires a much smaller skin contact area. Also, many antennas can be placed on a chest cavity, to obtain a well defined image of the chest cavity. The inventive antennas can be mathematically described as a point source, thus making analysis of the data easier. A conductive substance should be placed on the outside of the chest cavity, to permit a sufficient flow of electromagnetic energy into the chest cavity.

The prior art (Iskander et al.) has the drawback that the electric field vanishes at some distance from the tool face, since the fields in the two parallel slots are oppositely directed. No such cancellation occurs with the present invention. Furthermore, the incorporation of a resistor in Iskander et al's antenna introduces a power limitation.

In another embodiment, the present invention can be used in the field of microwave hyperthermia. The apparatus can couple electromagnetic energy into the interior portion of a mammal, so that the electromagnetic energy is focused to heat and thereby reduce the size of or destroy a tumor. Tumor reduction therapy or cancer therapy, by hyperthermia, combined with radiation or drugs is known in the art to either stop or slow down the growth of cancer cells, or cause the death of the cancer cells.

The present invention has the advantage over the prior art that many frequencies can be selected. Because there is no limitation to the power handling capability in the inventive antenna, the present invention is particularly suited for depositing microwave power into a localized area inside a

mammal, such as a human. Either a single antenna or an array of antennas could be used.

In yet another embodiment, the apparatus can be implanted inside the body of a mammal, and used as a radio frequency antenna. Either a single antenna or an array of antennas could be used. As the inventive antenna can be made very small (as small as approximately 10 mm long and approximately 5 mm high), it is particularly suitable to this application. As the antenna gets smaller, the frequency coverage shifts to higher frequencies. The apparatus can be constructed with a commercial micro-coaxial connector. However, smaller devices can be constructed through the use of a customized coaxial connector.

The apparatus can operate in the frequency domain, using a single frequency, multiple frequencies (such as simultaneous, selectable, or time-multiplexed for example), or swept frequency techniques. Or, the apparatus can operate in the time domain, using pulses of a wide variety of shapes, widths, rise and fall times, etc. When the pulses are transformed to the frequency domain, either electronically using a spectrum analyzer, or numerically using mathematical transforms, the same information is obtained as would be given by a frequency domain tool.

A prototype tool was constructed, with the inventive antennas. The tool consists of one transmitting and one receiving antenna, the distance between them being variable.

An acceptable dielectric antenna must meet the following criteria:

(i) It must be able to couple sufficient energy into and from the material at its operating frequency to allow probing of the material;

(ii) This probing energy must penetrate into the material, rather than clinging to the surface of the tool (i.e., it must travel as a freely propagating wave rather than a surface wave guided along the tool face).

In the present instance, the above two conditions must hold over the entire range of the frequency of operation.

The first of the above criteria is tested by measuring the return loss for the transmitting antenna, and the transmission loss from the transmitting to the receiving antenna - both as a function of frequency. These measurements are shown in Figure 4 where the tool is placed in air and against brine of conductivity 0.5 mho/m (to represent a biological medium). The return loss curve in brine shows that sufficient energy is entering the brine over the frequency range of the measuring device (Hewlett-Packard HP8505A Network Analyzer; 500 KHz - 1300 MHz) to permit probing. The transmission loss shows that sufficient energy is being received at the receiving antenna to permit measurements.

Measurements were made by using another measuring device (HP3577A Network Analyzer; 5Hz - 200 MHz) to test the low frequency limitation of the antenna. The results are shown in Figure 5, showing that the low frequency limitation is about 5 KHz. The improved return loss performance in the 200 MHz region (at Figure 4) results from a drying (curing) of the epoxy alumina filling between measurements.

Figure 6 shows time-domain transmission measurements at various distances (d). to a metal reflector plate in the brine. The change in amplitude of the received pulse as a function of the distance of the metallic reflector shows that the energy has penetrated into the brine out to the location of the plate.

While a preferred embodiment of the invention has been described and illustrated, it should be apparent that many modifications can be made thereto without departing from the spirit or scope of the invention. Accordingly, the invention is not limited by the foregoing description, but is only limited by the scope of the claims appended hereto.

CLAIMS:

1. Apparatus for coupling electromagnetic energy into materials comprising a measuring tool having a tool face, said measuring tool further comprising an electromagnetic transmitting antenna, said transmitting antenna further comprising:

(a) a coaxial cable connecting means and means to transmit electromagnetic energy therethrough;

(b) a stripline adapter capable of transmitting electromagnetic energy from said coaxial cable connecting means to a stripline having a metallic central strip, said center strip having a front end, a flat strip body, a flat strip face, and a distal end, said front end electrically connected to a center conductor of said stripline adapter, said strip face bent at approximately right angles to said strip body and having a height measured from said right angle bend to said distal end that is compatible with a desired frequency coverage;

(c) a ground plane which extends from said stripline adapter to said right angle bend, so that said distal end extends away from said ground plane and so that a void exists between said center strip and said ground plane;

(d) a dielectric largely filling said void, said dielectric comprised of a material having a very high dielectric constant and a very low energy loss, so that said transmitting antenna is positioned so that said ground plane is fixedly

connected to said measuring tool and said strip face is positioned to lie flush with said tool face so that said transmitting antenna can transmit electromagnetic energy into said material;

(e) an enclosure surrounding said stripline comprising four metallic walls, said walls positioned in electrical contact with said ground plane and said stripline adapter, so that said strip face is nearly centered in the opening created by said walls and said ground plane;

(f) a loss-less, non-conducting material which fills in any remaining open space in said enclosure so that said non-conducting material forms an additional wall that is nearly flat with said strip face;

(g) said receiving electromagnetic antenna comprised in essentially the same manner as said transmitting antenna, said receiving antenna positioned in said measuring tool in the same manner as said transmitting antenna, so that said receiving antenna can receive said electromagnetic energy which has traveled through said material; and

(h) means for monitoring the amplitude and the phase of said received electromagnetic energy.

2. Apparatus as recited in Claim 1 further comprising a means for positioning said tool face near said material.

3. Apparatus as recited in Claim 1 wherein said electromagnetic energy is focused to heat and thereby reduce the size of a tumor in a mammal.

4. Apparatus as recited in Claim 1 wherein said electromagnetic energy is focused to heat and thereby destroy a tumor in a mammal.

5. Apparatus as recited in Claim 1 wherein said antennas are positioned on a belt-mounted device.

6. Apparatus as recited in Claim 1, further comprising a plurality of receiving antennas.

7. Apparatus as recited in Claim 6 further comprising a plurality of transmitting antennas.

8. Apparatus as recited in Claim 7 wherein said materials are mammal tissue and water.

9. Apparatus as recited in Claim 1, wherein broadband measurements are taken to determine said dielectric properties as a function of position within said material.

10. An apparatus for coupling electromagnetic energy to determine the quantity of a fluid in a material, said apparatus having a tool face and further comprising a first electromagnetic transmitting antenna, said first transmitting antenna further comprising:

(a) a coaxial cable connecting means and means to transmit electromagnetic energy therethrough;

(b) a stripline adapter capable of transmitting electromagnetic energy from said coaxial cable connecting means to a stripline having a metallic central strip, said center strip having a front end, a flat strip body, a flat strip face, and a distal end, said front end electrically connected to a center conductor of said stripline adapter, said strip face bent at approximately right angles to said strip body and having a height measured from said right angle bend to said distal end that is compatible with a desired frequency coverage;

(c) a ground plane which extends from said stripline adapter to said right angle bend, so that said distal end extends away from said ground plane and so that a void exists between said center strip and said ground plane;

(d) a dielectric filling most of said void, said dielectric composed of a material having a very high dielectric constant and a very low energy loss, so that said first transmitting antenna is positioned so that said ground plane is fixedly connected to said logging tool and said strip face is positioned to lie flush with said tool face so that said first transmitting antenna can transmit electromagnetic energy into said material;

(e) an enclosure surrounding said stripline comprising four metallic walls, said walls positioned in electrical contact with said ground plane and said stripline adapter, so that said strip face is

nearly centered in the opening created by said walls and said ground plane;

(f) a loss-less, non-conducting material which fills in any remaining open space in said enclosure so that said non-conducting material forms an additional wall that is nearly flat with said strip face;

(g) said receiving electromagnetic antenna comprised in essentially the same manner as said transmitting antenna, said receiving antenna positioned in said apparatus in the same manner as said transmitting antenna, so that said receiving antenna can receive said electromagnetic energy which has traveled through said material; and

(h) means for monitoring the amplitude and the phase of said electromagnetic energy, so that the quantity of said fluid can be determined.

11. Apparatus as recited in Claim 1 or 10 wherein said transmitting antenna transmits and said receiving antenna receives electromagnetic energy over a frequency range of 2 KHz to 4 GHz.

12. Apparatus is recited in Claim 1 or 10 wherein said transmitting antenna can alternately function as a receiving antenna and said receiving antenna can alternately function as a transmitting antenna.

13. Apparatus as recited in Claim 12 further comprising a belt-mount, said belt-mount substantially conforming to

the outside of a mammal tissue and holding said transmitting and receiving antennas.

14. Apparatus as recited in Claim 13 further comprising a plurality of receiving antennas.

15. Apparatus as recited in Claim 14 further comprising a plurality of transmitting antennas.

16. Apparatus as recited in Claim 10 wherein said fluids are water.

17. Apparatus as recited in Claim 1 or 10 wherein said ground plane is no greater than 10 mm in length.

18. Apparatus as recited in Claim 1 or 10 wherein said strip face has a height that is no greater than 5 mm.

19. Apparatus as recited in Claim 1 or 10 wherein said electromagnetic energy is monitored to provide an indication of the amount and distribution of a fluid inside mammal tissue.

20. Apparatus as recited in Claim 1 or 10 wherein no receiving antenna is incorporated.

21. Apparatus as recited in Claim 1 or 10 wherein said apparatus is implanted inside a mammal, as a radio frequency antenna.

22. Apparatus as recited in Claim 21 wherein said apparatus does not incorporate a receiving antenna.

23. Apparatus as recited in Claim 1 or 10 wherein a strip transmission line is electrically connected to said stripline, so that electromagnetic energy can be transmitted thereto.

24. Apparatus as recited in Claim 10 wherein said nature of said fluid is determined as a function of position in said material.

25. Method for coupling electromagnetic energy into materials comprising the steps of:

forming a measuring tool having a tool face, an electromagnetic transmitting antenna and a receiving antenna, said transmitting antenna further comprising:

(a) a coaxial cable connecting means and means to transmit electromagnetic energy therethrough;

(b) a stripline adapter capable of transmitting electromagnetic energy from said coaxial cable connecting means to a stripline having a metallic central strip, said center strip having a front end, a flat strip body, a flat strip face, and a distal end, said front end electrically connected to a center conductor of said stripline adapter, said strip face bent at approximately right angles to said strip body and having a height measured from said right angle bend to said distal end that is compatible with a desired frequency coverage;

(c) a ground plane which extends from said stripline adapter to said right angle bend, so that said distal end extends away from said ground plane and

so that a void exists between said center strip and said ground plane;

(d) a dielectric largely filling said void, said dielectric comprised of a material having a very high dielectric constant and a very low energy loss, so that said transmitting antenna is positioned so that said ground plane is fixedly connected to said measuring tool and said strip face is positioned to lie flush with said tool face so that said transmitting antenna can transmit electromagnetic energy into said material;

(e) an enclosure surrounding said stripline comprising four metallic walls, said walls positioned in electrical contact with said ground plane and said stripline adapter, so that said strip face is nearly centered in the opening created by said walls and said ground plane;

(f) a loss-less, non-conducting material which fills in any remaining open space in said enclosure so that said non-conducting material forms an additional wall that is nearly flat with said strip face;

(g) said receiving antenna comprised in essentially the same manner as said transmitting antenna, and positioned in said measuring tool in the same manner as said transmitting antenna, so that said receiving antenna receives said electromagnetic energy which has traveled through said material;

interconnecting said measuring tool with a means for monitoring said electromagnetic energy whereby said dielectric properties can be measured; and

interconnecting said measuring tool with a source of electromagnetic energy.

26. Method as recited in Claim 25 further comprising a means for positioning said tool face near said material.

27. Method as recited in Claim 25 wherein said electromagnetic energy is focused to heat and thereby reduce the size of a tumor in a mammal.

28. Method as recited in Claim 25 wherein said electromagnetic energy is focused to heat and thereby destroy a tumor in a mammal.

29. Method as recited in Claim 25 wherein said antennas are positioned on a belt-mount device.

30. Method as recited in Claim 25 further comprising a plurality of receiving antennas.

31. Method as recited in Claim 30 further comprising a plurality of transmitting antennas.

32. Method as recited in Claim 31 wherein said materials having dissimilar dielectric properties are mammal tissue and water.

33. Method as recited in Claim 25 wherein said broadband measurements are taken to determine said dielectric

properties as a function of position within said material.

34. Method for coupling electromagnetic energy to determine the quality of a fluid in a material, comprising the steps of:

forming an apparatus having a tool face, an electromagnetic transmitting antenna, and a receiving antenna, said transmitting antenna further comprising:

(a) a coaxial cable connecting means and means to transmit electromagnetic energy therethrough;

(b) a stripline adapter capable of transmitting electromagnetic energy from said coaxial cable connecting means to a stripline having a metallic central strip, said center strip having a front end, a flat strip body, a flat strip face, and a distal end, said front end electrically connected to a center conductor of said stripline adapter, said strip face bent at approximately right angles to said strip body and having a height measured from said right angle bend to said distal end that is compatible with a desired frequency coverage;

(c) a ground plane which extends from said stripline adapter to said right angle bend, so that said distal end extends away from said ground plane and so that a void exists between said center strip and said ground plane;

(d) a dielectric largely filling said void, said dielectric comprised of a material having a very

high dielectric constant and a very low energy loss, so that said transmitting antenna is positioned so that said ground plane is fixedly connected to said measuring tool and said strip face is positioned to lie flush with said tool face so that said transmitting antenna can transmit electromagnetic energy into said material;

(e) an enclosure surrounding said stripline comprising four metallic walls, said walls positioned in electrical contact with said ground plane and said stripline adapter, so that said strip face is nearly centered in the opening created by said walls and said ground plane;

(f) a loss-less, non-conducting material which fills in any remaining open space in said enclosure so that said non-conducting material forms an additional wall that is nearly flat with said strip face;

(g) said receiving antenna comprised in essentially the same manner as said transmitting antenna, and positioned in said apparatus in the same manner as said transmitting antenna, so that said receiving antenna receives said electromagnetic energy which has traveled through said material;

interconnecting said measuring tool with a means for monitoring said electromagnetic energy whereby said nature of said fluid can be determined; and

interconnecting said apparatus with a source of electromagnetic energy.

35. Method as recited in Claim 31 or 40 wherein said transmitting antenna transmits and said receiving antenna receives electromagnetic energy over a frequency range of 2 KHz to 4 GHz.

36. Method as recited in Claim 25 or 34 wherein said transmitting antenna can alternately function as a receiving antenna and said receiving antenna can alternately function as a transmitting antenna.

37. Method as recited in Claim 36 further comprising a belt-mount, said belt-mount substantially conforming to the outside of a mammal tissue and holding said transmitting and receiving antennas.

38. Method as recited in Claim 37 further comprising a plurality of receiving antennas.

39. Method as recited in Claim 38 further comprising a plurality of transmitting antennas.

40. Method as recited in Claim 39 wherein some of said antennas are positioned on said tool face and some antennas are positioned on said belt-mount.

41. Method as recited in Claim 34 wherein said fluids are water.

42. Method as recited in Claim 25 or 34 wherein said ground plane is no greater than 10 mm in length.

43. Method as recited in Claim 25 or 34 wherein said strip face has a height that is no greater than 5 mm.

44. Method as recited in Claim 25 or 34 wherein said electromagnetic energy is monitored to provide an indication of the amount and distribution of a fluid inside mammal tissue.

45. Method as recited in Claim 25 or 34 wherein no receiving antenna is incorporated.

46. Method as recited in Claim 25 or 34 wherein said apparatus is implanted inside a mammal, as a radio frequency antenna.

47. Method as recited in Claim 46 wherein said apparatus does not incorporate a receiving antenna.

48. Method as recited in Claim 25 or 34 wherein a strip transmission line is electrically connected to said stripline, so that electromagnetic energy can be transmitted thereto.

49. Method as recited in Claim 40 wherein said quantity of said fluid is determined as a function of position within said material.

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Relevant Technical fields

(i) UK Cl (Edition K) G1N (NCLA, NCLE, NCLL, NENX)

(ii) Int Cl (Edition 5) A61B, A61N, G01V

Databases (see over)

(i) UK Patent Office

(ii)

Search Examiner

D J MOBBS

Date of Search

28 FEBRUARY 1992

Documents considered relevant following a search in respect of claims 1-49

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
A	US 4678997 (JANES)	

SF2(p)

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Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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